RESEARCH ARTICLE

Acetone sensing properties of spray deposited In : ZnO Thin Films

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ABSTRACT
Indium doped ZnO thin films were prepared by simple and cost effective chemical spray pyrolysis technique. The effect of In doping (1 at% to 4 at %) on Acetone gas sensing properties were studied. The In: ZnO sensors show different responses for different nanostructures. The Acetone response is higher at an optimum operating temperature of the film and it is lower on either side of operating temperature. The response and recovery times of the Indium doped ZnO films were enhanced significantly compared to those reported for ZnO films. The response of 3% In doped ZnO film to Acetone is considerable than that others.

Keywords: Spray pyrolysis; In-doped ZnO films; Acetone, response time, recovery time.

INTRODUCTION

Zinc oxide (ZnO) is one of the most important metal-oxide semiconductors. It is an n-type semiconductor of hexagonal (wurtzite) structure with a direct energy wide-band gap of about 3.37 eV at room temperature. Because of its good electrical and optical properties, low cost and absence of toxicity, this material has got wide applications in electronic and optoelectronic devices such as transparent conductors, solar cell windows, gas sensors, heat mirrors, etc. [1–6]. For gas sensor purposes, this material has been investigated in various forms such as single crystals, sintered pellets, thick films, thin films and hetero-junctions [7–12].

In the recent past, there has been an increasing degree of awareness on using transition metals as a dopant for ZnO in view of tailoring its electrical, optical and sensing properties [2–5]. Many deposition techniques like molecular beam epitaxy (MBE) [6], RF sputtering [7,8], chemical vapour deposition [9,10], thermal evaporation [11], pulsed laser deposition [12,13], spray pyrolysis [14,15], sol–gel technique [16], etc.

were employed for coating ZnO films. Out of these, spray pyrolysis technique has gained a significant degree of interest due to its simplicity, safety and usage of low cost equipments together with less expensive raw materials.

For the efficient sensing methods based on ZnO thin films, it becomes imperative to employ less expensive and easy techniques for depositing In doped ZnO films. Hence, an attempt is made to focuses on the study of the structural, optical, electrical and sensing properties of In doped ZnO thin films, deposited using spray pyrolysis technique.

METHODOLOGY

In-ZnO thin films were deposited on the pre-heated glass substrates by simple and cost effective spray pyrolysis technique at 400 ^{0}C, Spray rate 2.5 ml/min, substrate to nozzle distance 30 cm and molar concentration was 0.5 M. The precursor used was Zinc acetate dehydrated ($Zn(C_2H_3O_2)_2.2H_2O$). The Indium chloride was the doping source. The In percentage in the solution was varied from 1 at% to 4 at% in the starting solution. The prepared solution is then sprayed on the heated glass substrates which transforms the solution (mixture) to a stream formed with uniform and fine droplets.

The gas sensor was made by pressing the powder in the form of pellet. The gas sensing characteristics with reference to time at different operating temperatures and concentrations were recorded. The gas response (S) for a given test gas was calculated using following equation.

$$S\,(\%) = \frac{R_{air} - R_{gas}}{R_{air}} \times 100$$

where, R_{air} and R_{gas} are the resistance of the sensor in air and in the test gas, respectively.

RESULTS

1 Effect of temperature

Fig. 1 depicts the Acetone response as a function of operating temperature for In: ZnO thin films obtained at 1000 ppm of acetone. The response study showed that increase in temperature gas response also increases up to 573 K and then decreased with further increase in temperature. At low operation temperature, the low response can be expected because the gas molecules do not have enough thermal energy to react with the surface adsorbed oxygen species.

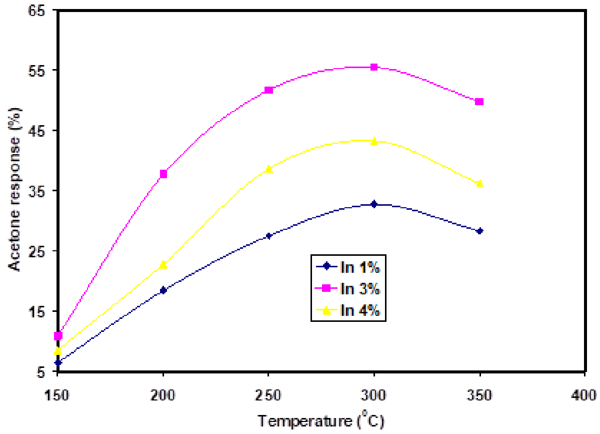

Fig. 1: Acetone response of In: ZnO film 1000 ppm acetone at different temperatures.

2 Dynamic gas response transients of In: ZnO film

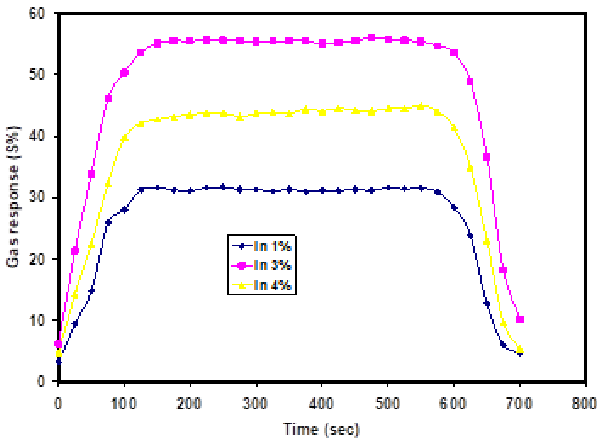

Fig. 2: Dynamic acetone transient response of In doped ZnO films

Fig. 2 shows the dynamic gas response transients of In: ZnO films of different In concentrations upon exposure to 1000 ppm of acetone at 573 K. The response went on increasing with In doping. The maximum response was obtained with film In 3 at%. The grain size and porosity of the film played an important role.

3 Response and recovery time periods

Fig. 3 and Fig. 4 shows the variation of response and recovery time, respectively, with film having different In doped ZnO thin films at 573 K for 1000 ppm Acetone. It is observed that both the response and recovery times decrease first with increasing In percentage and again increase with the further increase in In concentration. The smallest response time of 100 s and the recovery time of 90 s obtained for sample with 3 at% might be due to non spherical grains which are not able to trap gas molecules.

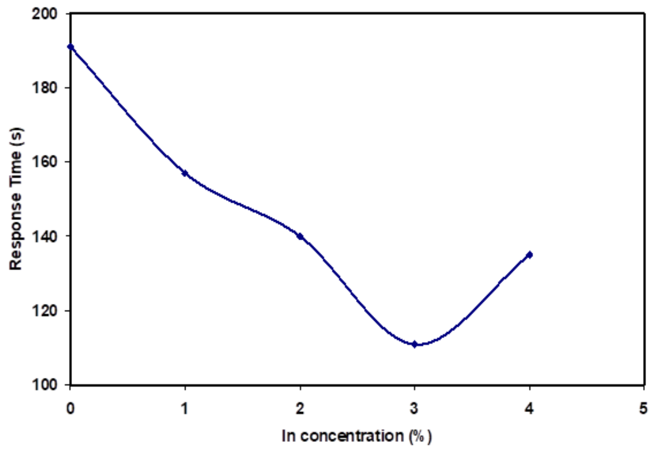

Figure 3: Acetone Response time of In doped ZnO films.

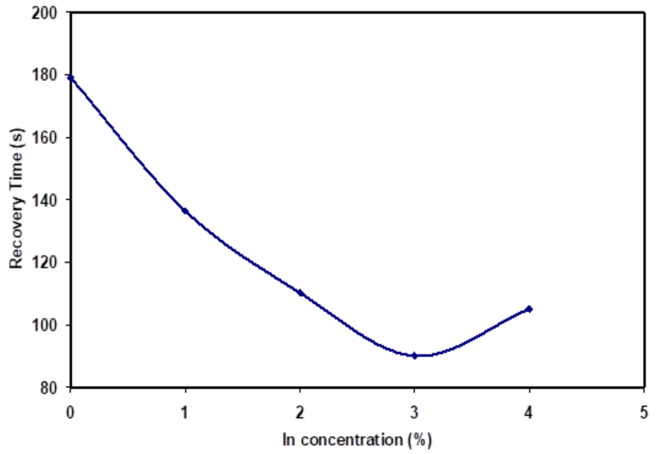

Fig. 4: Acetone Recovery time of In doped ZnO films.

CONCLUSION

The effect of Indium doping (1 at% to 4 at%) on the acetone gas sensing properties were studied. The sensors response gradually increases up to 300 °C and then starts to saturate. The response and recovery times of the In: ZnO films were enhanced significantly. The response time of 100 s and corresponding recovery time is 90 s is observed for 3% In doped ZnO thin film.

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